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NASA TM-81849

NASA-TM-81849 19800025710

NASA Technical Memorandum 81849

PREDICTED AIRFRAME NOISE LEVELS

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INTRODUCTION

Concern over predicted airframe noise levels as they appeared in a paper by P. Block (ref. 1) has been voiced by the major aircraft manufacturers in the U. S. The controversy stems mainly from figure 13 in reference 1 where predicted airframe noise levels for a number of aircraft types are shown together with the FAR 36 stage 3 approach noise rule and some approach noise certification data points. The predicted airframe noise levels in this figure are significantly lower than the stage 3 approach noise rule. The concern of the manufacturers related to technical matters is focused upon the possibility that (1) regulatory agencies may use these predicted airframe noise levels as a basis for setting approach noise rules in the future; and (2) the airframe noise prediction method adopted in ANOPP may underpredict airframe noise by a significant margin.

The aircraft approach speed and flap setting used by Block to compute the airframe noise were obtained from a summary published in Aviation Week and Space Technology and these parameters were clearly identified in reference 1. However, these conditions were not the same as required for certification, but rather the conditions for the expected normal operations of these aircraft. Therefore, there is some inconsistency in the representation of this particular figure in reference 1. In order to rectify this inconsistency and to clarify the concern existing in the industry, this document will describe the ANOPP airframe noise prediction method and the computational results specifically related to six aircraft which are part of the current commercial airline fleet.

CERTIFICATION CONDITION

The aircraft approach speeds and flap settings used by P. Block in reference 1 are given in table I. These values were obtained from a summary published in the March 12, 1979 issue of Aviation Week and Space Technology. These landing speeds and flap settings do not correspond to the conditions required for noise certification. The certification approach speeds are generally higher than the approach speeds as shown in reference 1.

The certification approach speeds and flap settings for the six aircraft considered in this document, namely, DC-9-30, Boeing 727-200, A300-B2 Airbus, DC-10-10, L-1011, and Boeing 747-200B, have been obtained from FAA and the values are also shown in table I.

N80-34218 #

COMPUTATIONS OF AIRFRAME NOISE

In order to address the points of concern outlined in the Introduction, airframe noise has been computed in several ways for the six aircraft under consideration. First, the airframe noise computations have been repeated for the conditions specified in ref. 1. The ANOPP airframe noise prediction method is the one developed and published by M. R. Fink in 1977 (ref. 2). In this set of computations, the atmosphere is chosen as the ISA standard +10° centigrade day at sea level, and ground reflection effects at the microphone position have been included. The results are identical to those reported in reference 1 as expected since the ANOPP airframe noise computation module has not been modified since the computations were executed for reference 1. A second set of airframe noise levels are calculated by using the certification approach conditions which are specified in table I. The results for both sets of computations are tabulated in table II. Since the airframe noise intensity depends on the fifth power of the aircraft speed, the higher approach speed during certification resulted in an average increase in noise of 2.5 EPNdB for these six aircraft. In particular, the predicted airframe noise of DC-9-30, B-727, and A300-B2 Airbus for certification are significantly higher than the corresponding levels given in reference 1 for nominal aircraft operating conditions.

Since the publication of reference 2, additional information regarding the physical behavior of airframe noise has become available. Based on this new information, some changes to the airframe noise prediction method were recommended by Fink. In his method the main contributions to airframe noise are produced by the landing gear and the trailing edge flap. In the original Fink prediction method, directivity patterns for these two components are static dipoles. The gear noise dipole is normal to the flight path while the trailing edge flap dipole is normal to the plane of the flap. The modifications recommended by Fink are as follows:

1. The directivity pattern of the gear noise component should be changed to a convected monopole. The OASPL radiated at 90 degrees from the flight path should remain the same as previously given in reference 2.
2. The directivity of the trailing edge flap noise component should be changed to a convected dipole pattern. The OASPL radiated along the axis of the dipole should remain unchanged. However, in the new directivity pattern the dipole axis is in a direction normal to the flight path regardless of the flap angle setting.

In both cases, the convection factor is suggested to be $(1-M_a \cos\theta)^{-3}$, which is based upon empirical data correlation. These changes in directivity result in a net increase in total radiated sound power.

Since these changes appear to be reasonable from an analytical standpoint, a third set of airframe noise levels are computed according to these modifications recommended by Fink. The results are also tabulated in table II. In this set of computations, the input is chosen to be the certification approach

conditions. It can be seen from table II that the modifications in directivity result in an increase in noise level of approximately 1.5 EPNdB on average for the six aircraft. Therefore, between the predicted airframe noise at certification approach conditions using a modified Fink method and the predicted airframe noise as shown in reference 1, a net increase in level of about 4 EPNdB is observed on the average. The computational results are also summarized in figure 1.

THE ISSUE OF SPECTRAL MODIFICATION

In light of the concern over the possibility of underprediction of airframe noise by the Fink method as given in reference 2, the basis for arriving at the recommended spectrum for the trailing edge flap noise has also become an issue. Reference 2 recommends separate spectra for flaps with two segments and three segments. The three segment spectrum has a much higher composition of high frequency noise. The original data base used by Fink contains seven sets of data with three sets coming from measurements of VC-10 aircraft (fig. 2). It is evident from figure 2 that the VC-10 flap noise spectra are rich in high frequency components. In reference 2, Fink treated the VC-10 as a three-segment flap system while it has actually a two-segment flap system. As a consequence, the VC-10 data were correlated with the Boeing 747 data to determine the three-segment flap spectrum. Because of this error, the correct recommendation for the flap noise spectra is now at issue.

Fink has recently recommended that the three-segment flap noise spectrum should be used for predicting the flap noise component for large airplanes with either a two-segment flap system or a three-segment flap system. However, this recommendation is not adopted for ANOPP computations because, this particular change in procedure by itself increases the predicted EPNL by approximately 5.5 EPNdB, and such levels for the L-1011, and DC-10 would have exceeded, by a significant margin, the airframe noise levels suggested by the manufacturers in reference 3. Therefore, the merit of this particular change in prediction procedure is questionable. In essence, the only data of airframe noise for a wide body jet within the data base for the development of the spectral curve are provided by the recent measurement of airframe noise of an L-1011 by Fethney and Jelly (ref. 4). The Fink recommendation is made, therefore, with minimal support of data. While it is possible that the current two-segment flap spectrum is deficient in high frequency levels, a new recommended standard spectrum cannot be established without a careful reevaluation of the evidence.

CONCLUSIONS

Based on computations of airframe noise levels for six important types of commercial aircraft, the inconsistency in a key figure previously published by Block in reference 1 has been rectified. After using the correct certification approach conditions and incorporating some modifications to the Fink

method of airframe noise prediction, the predicted airframe noise levels have shown a net increase of about 4 EPNdB as compared with the levels given in reference 1.

REFERENCES

1. Block, P. J. W.: Assessment of Airframe Noise. AIAA Paper 79-4148, J. Aircraft, vol. 16, no. 12, Dec. 1979, pp. 834-841.
2. Fink, Martin R.: Airframe Noise Prediction Method. Federal Aviation Administration Report FAA-RD-77-29, March 1977.
3. AIA Position Paper on Airframe Noise Levels and Research Programs. Transmitted by letter from J. C. Snodgrass, Jr., Director, Aviation Programs, Aerospace Industries Association of America, Inc. to Chief, ASD, LRC, July 25, 1980.
4. Fethney, P. and Jelly A. H.: Airframe Self-Noise Studies on the Lockheed L01011 Tristar Aircraft. AIAA Paper 80-1061, June 1980.

TABLE I. AIRFRAME NOISE PREDICTION STUDY

Input Parameters

Aircraft	No. of Flap Segments	TOGW (Mega Newton)	ORIGINAL (J. Aircraft)		CERTIFICATION	
			Velocity (m/sec)	Flaps (deg)	Velocity (m/sec)	Flaps (deg)
DC-9-30	2	0.505	64.43	45	73.6	40
727-200	3	0.780	64.84	30	71.55	40
A300-B2	2	1.390	67.94	45	83.50	25
L-1011	2	1.915	73.34	45	77.16	42
DC-10-10	2	1.825	70.64	45	77.16	50
747-200B	3	3.440	72.44	45	85.14	30

TABLE II. AIRFRAME NOISE PREDICTION STUDY

Approach EPNL

Aircraft	ORIGINAL (J. Aircraft)	CERTIFICATION	
		Current AFM Module	Modified AFM Module
DC-9-30	84.3	87.2	88.7
727-200	89.6	93.6	94.9
A300-B2	88.5	91.8	93.9
L-1011	90.2	91.2	93.1
DC-10-10	90.3	92.8	94.8
747-200B	97.5	99.6	100.9

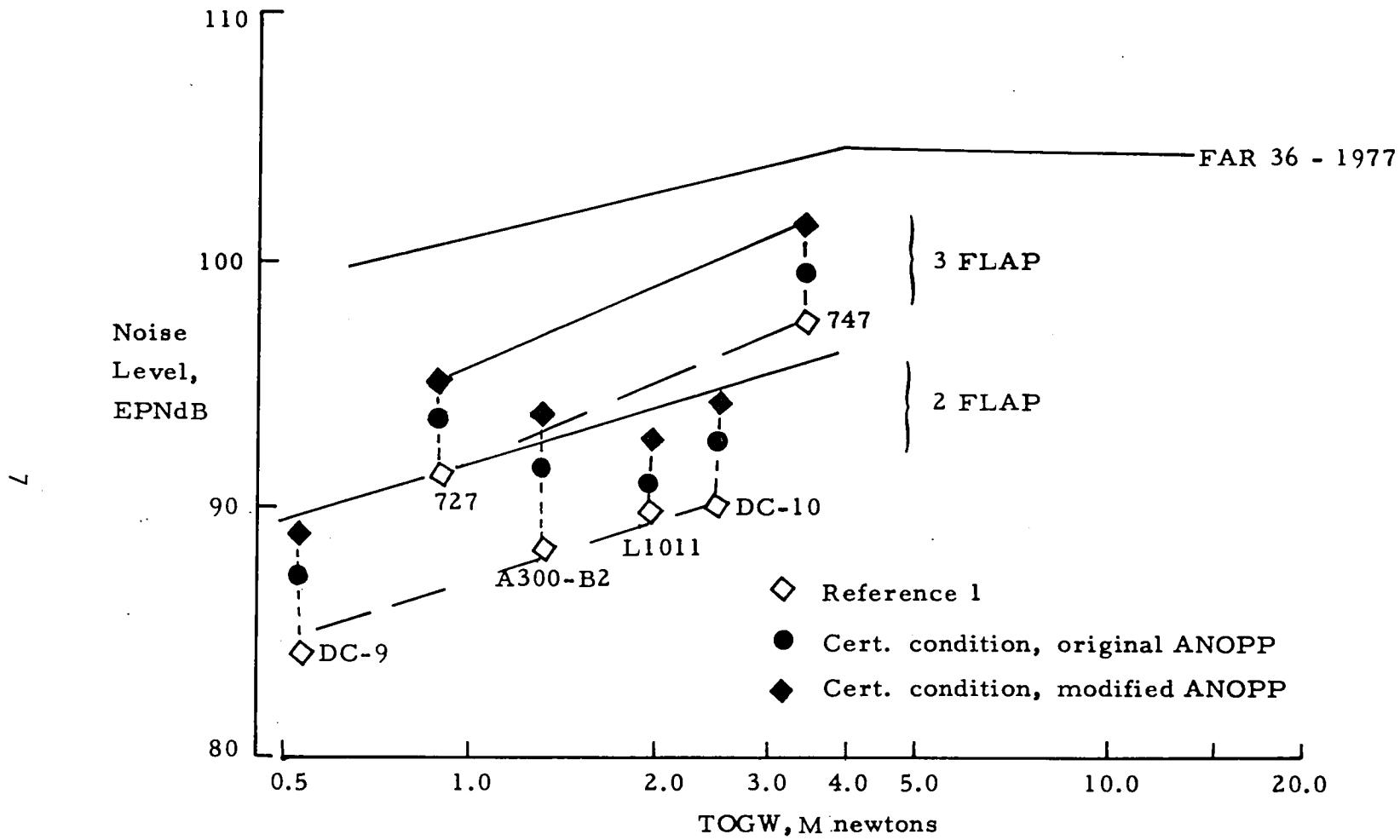


Figure 1. Predicted airframe noise levels, approach.

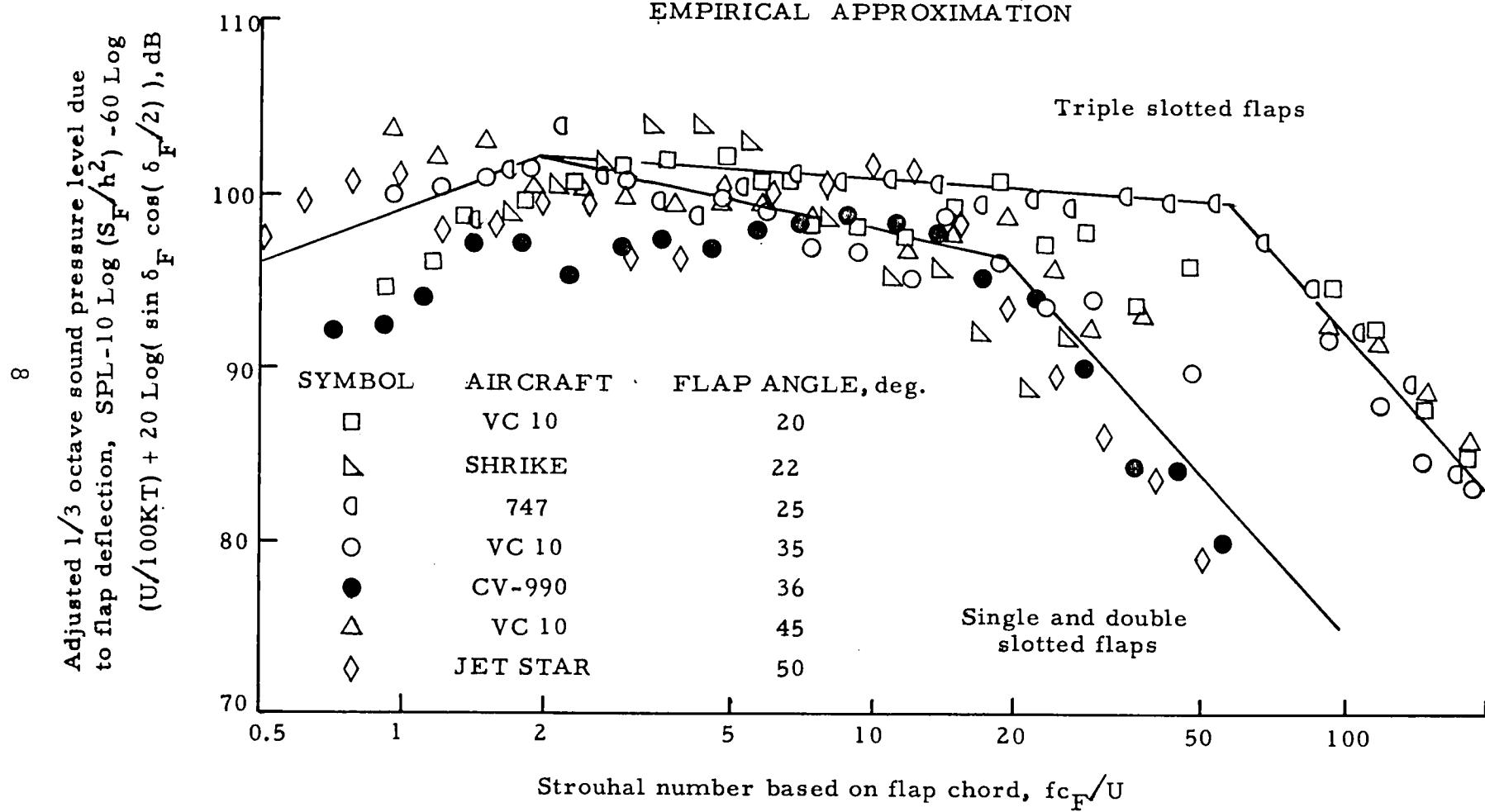


Figure 2. Measured airframe noise data.

1. Report No. NASA TM-81849	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Predicted Airframe Noise Levels		5. Report Date September 1980	6. Performing Organization Code
7. Author(s) J. P. Raney		8. Performing Organization Report No.	
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Virginia 23665		10. Work Unit No. 505-32-03	11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546		13. Type of Report and Period Covered Technical Memorandum	14. Sponsoring Agency Code
15. Supplementary Notes			
16. Abstract Calculated values of airframe noise levels corresponding to FAA noise certification conditions for six aircraft are presented: DC-9-30, Boeing 727-200, A300-B2 Airbus, Lockheed L-1011, DC-10-10, and Boeing 747-200B. The prediction methodology employed is described and discussed.			
17. Key Words (Suggested by Author(s)) Airframe Noise Prediction Aircraft Noise ANOPP		18. Distribution Statement Unclassified - unlimited Subject Category 71	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 8	22. Price* A02



